



Groundwater Primer for the Santa Rosa Plain

December 2011

GENERAL GROUNDWATER CONCEPTS

Hydrologic Cycle

All water on the surface of the earth and underground are part of the hydrologic cycle, driven by natural processes that constantly transform water from liquid to solid or vapor and back to liquid while moving it from place to place.

Water evaporates from ponds, lakes, oceans, reservoirs, and soils. Plants take water from the ground and emit water vapor into the air called evapotranspiration. The water vapor forms clouds that eventually condense and return to the earth's surface as precipitation such as fog, rain, sleet, or snow.

During storms, water runs off the surface into streams or water bodies or seeps into the ground. Water that sinks into soils or surface rock recharges groundwater reservoirs or aquifers. Groundwater can discharge at seeps or springs, or into rivers, streams, lakes and oceans, or wells. In arid areas and during the summer, precipitation may first infiltrate into the ground, but much of it quickly returns to the cycle through evapotranspiration.

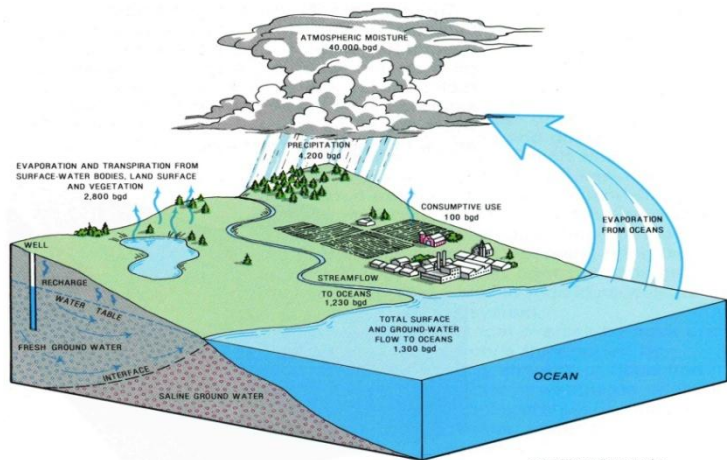


Figure 1: The Hydrologic Cycle – The Earth contains a finite amount of water as is illustrated here, showing how the water moves, from the oceans by evaporation, falling as precipitation back to the land and moving through streams, into lakes and into the subsurface as groundwater.

How to Stay Involved

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What Is Groundwater?

Groundwater is water that collects underground. It is held in an upper unsaturated zone and a lower saturated (groundwater) zone.

The **unsaturated zone** is located immediately beneath the land surface and above the water table, and the zone's pore spaces contain both air and water. Forces exerted by soil and rock surfaces bind water drops or films in the pore spaces. A well

drilled into the unsaturated zone will not produce water because the water drops or films attach too tightly to the surfaces to be pumped.

In the **saturated zone** all the open spaces are filled with water. The top of the saturated zone is called the water table. **The saturated zone supplies water to wells.** Like surface water, groundwater flows from higher to lower levels, under the influence of gravity. The pressure or elevation difference between higher and lower levels is called the hydraulic head.

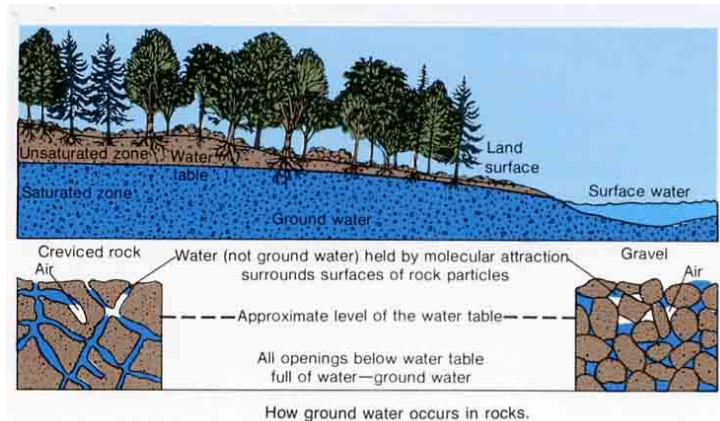


Figure 2: Schematic showing the unsaturated and saturated zones, and the occurrence of groundwater in porous media (right bottom - alluvial sands and gravels), and fractured hard rock (left bottom). Fractures in hard rock typically range from a few millimeters to more than a centimeter.

“The saturated zone supplies water to wells.”

Finding Groundwater

Sediment and rock characteristics determine where groundwater may be tapped for human use. Wells produce water from two general types of geologic materials:

- 1 **Sediments:** Sediments are made up of gravel, sand, silt and clay. Coarse gravel and sand sediment in and near stream channels tend to have abundant pore spaces between grains that allow groundwater to readily flow. Fine silt- and clay sediments tend to have very little pore spaces and do not transport water as rapidly.
- 2 **Bedrock:** Bedrock is a general term for solid rock, such as granite or sandstone, that lies beneath soil and sediments. In bedrock, most of the water is held and flows through fractures in the rock.

The amount of available groundwater depends on porosity and permeability. Groundwater moves through the open pore spaces between sediment grains. The porosity of the sediment or sedimentary rock is the volume of pore spaces divided by the total volume of rock, usually expressed as percent porosity.

The permeability, also called hydraulic conductivity, of the porous sediment or rock measures the ability of water to move through the material. Permeability depends on many factors, including porosity, grain size and distribution, and grain shape and arrangement. Although clay is considered to have a high porosity and water holding capacity, its permeability is very low due to the lack of connection between pore spaces. In contrast, gravels have both a high porosity and permeability, as it typically contains open and connected pore spaces.

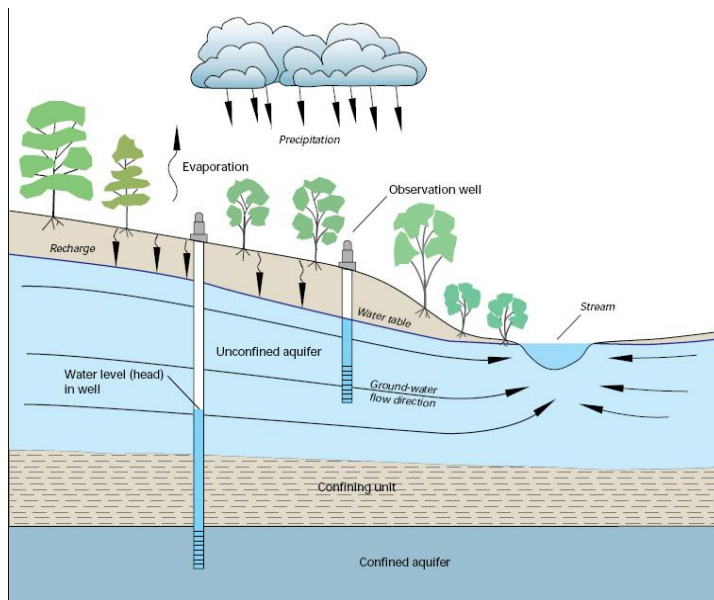


Figure 3: Recharge of groundwater, groundwater flow and interconnection of surface water, showing wells completed in unconfined and confined aquifers.

There are many different types of rock, and porosity can form in a variety of ways. Bedrock, such as granite, has porosity in the fractures that form over time. Volcanic rocks can have porosity from holes in the rock and also fractures. Fractures occur from the varying stresses within the earth or from weathering processes at the earth's surface.

Fractures are generally quite small, on the order of a few millimeters to more than a centimeter wide, but vary significantly at local and regional scales, and even on the scale of a well site. While exceptions exist, the yield from wells in fractured bedrock is generally much lower than yields from wells in sediments.

Aquifers

An aquifer is a saturated zone of sediment or rock with high enough permeability to transmit groundwater, yielding economically significant quantities of water to wells and springs. Groundwater stored in aquifers can be pumped to the surface through wells to supply water for agriculture, homes and cities.

Saturated sediments and rocks are called aquifers when they are permeable enough to transmit water sufficient to supply a residence, farm, town, or city. Aquifers are complex environments that can be highly variable in composition and how they influence the direction of groundwater flow and affect the water quality.

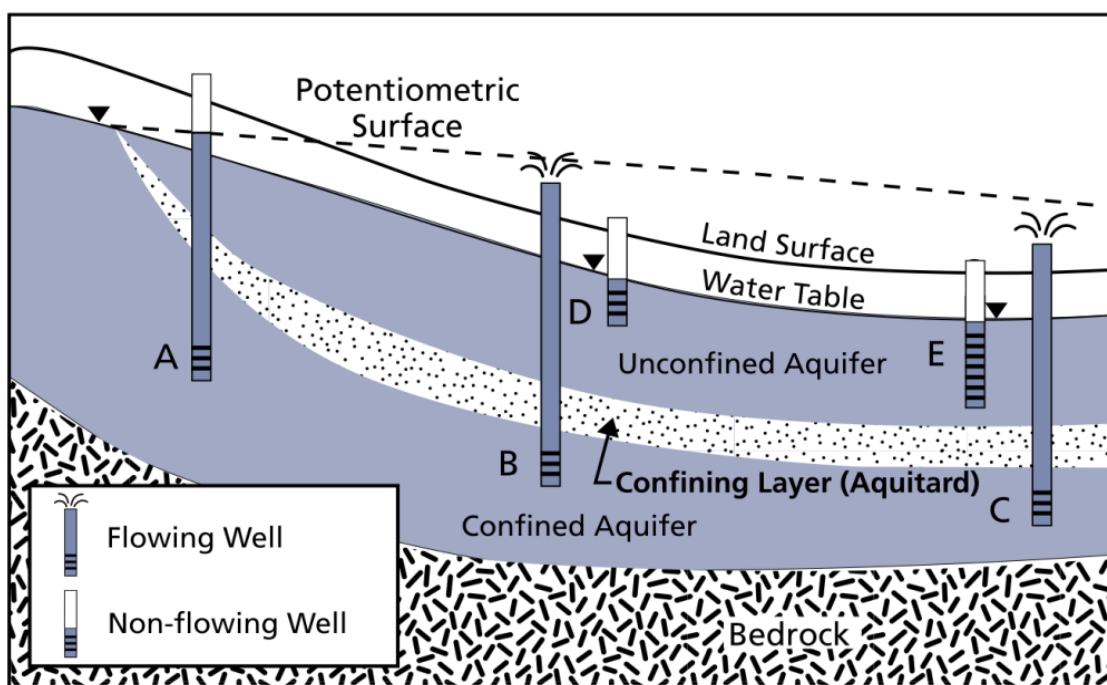


Figure 4: Types of aquifers showing groundwater levels in wells in unconfined (or water table), and confined.

While aquifers may be thought of as underground reservoirs, storing water underground is more complex than in a surface reservoir. An aquifer is something like a sponge, but made of various rock materials with variously-sized open spaces. The water surface and flow patterns within aquifer material are not visible from the surface, and groundwater reservoirs take much longer to fill and extract water from than a surface reservoir.

Aquifers can be either unconfined or confined (under pressure). Figure 4 illustrates the difference between an unconfined aquifer and a confined aquifer both of which occur below the unsaturated zone in the saturated zone. Unconfined aquifers are open to the atmosphere and are bounded at the top by the water table, which forms the transition between the unsaturated and saturated zones. Confined aquifers are typically found beneath unconfined aquifers and are separated by low permeability silt or clay confining layers (or aquitards).

Groundwater pressure varies depending on the aquifer. The groundwater level in a well completed in an unconfined aquifer will be the same as the water table (wells D and E) and, like surface water, will be at atmospheric pressure.

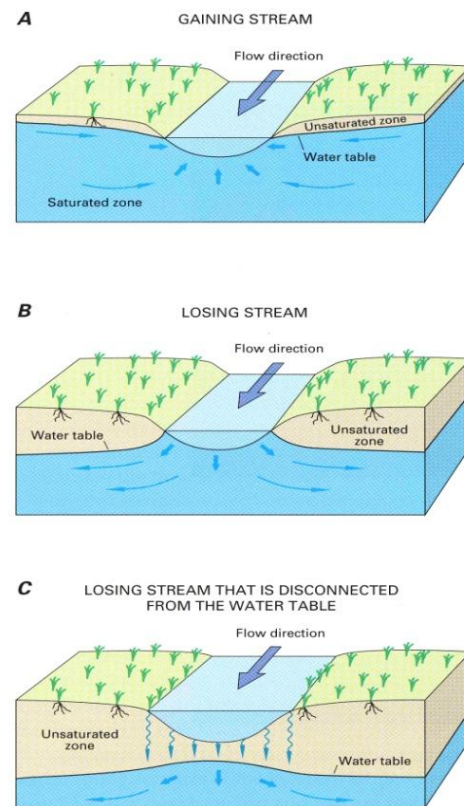
The groundwater in a confined aquifer is under a pressure greater than atmospheric pressure. When a well penetrates the layer that confines the aquifer, the water will rise in the well to the potentiometric surface level of the confined aquifer (wells A, B and C). The potentiometric surface is determined by the confined aquifer's highest elevation.

Where there is substantial rainfall, the water table generally mimics a slightly flattened outline of the land surface. In arid zones the water table is much flatter and frequently much deeper than in more temperate zones.

Surface Water and Groundwater Interaction

Surface water is commonly connected to groundwater, but the relationship is difficult to observe and measure. The relationship between surface water and groundwater depends on the amount of water available in the stream and in local aquifers, as well as the subsurface geology. Under natural hydrologic conditions, some streams gain flow from groundwater (Figure 5-A, right) and other streams lose flow to groundwater (Figures 5-B and C, right). Thus, in some areas (gaining streams) groundwater aquifers can help support streamflow during dry weather conditions and in other areas (losing streams) surface water bodies are important sources of recharge to groundwater aquifers. Streams can also shift between gaining and losing flow along their courses when the hydrology, underlying geology, local climate, or streamflow conditions change.

Figure 5: (A) Gaining streams receive water from the groundwater system. (B) Losing streams lose or add water to the groundwater system. (C) Disconnected streams are separated from the groundwater system by an unsaturated zone.



Groundwater Movement

Groundwater is generally hidden from view and therefore its presence and movement through the aquifers cannot be tracked visually. Collecting and evaluating well and stream-flow data can provide good information about groundwater flow and quality. Information from multiple wells is used to determine where groundwater is present and which way it is flowing.

Aquifers recharge whenever precipitation or surface water supplies exceed evapotranspiration. Gravity moves groundwater away from recharge areas toward natural discharge areas. In an unconfined aquifer, an increase in water level is caused by adding water to the aquifer. In a confined aquifer, an increase in pressure is the result of an increase in the height of water in the recharge areas. As the aquifer's pressure decreases, the level of discharge also will decrease.

Time provides another complexity. The rate of movement depends on a variety of factors:

- Hydraulic conductivity, also known as permeability—a measure of how much water the rock can transmit;
- fluid viscosity or the thickness of the fluid; and,
- the gradient or slope of the water table.

Water that recharges an aquifer does not immediately supply a pumping well, but may take days to centuries or more to reach a well site.

Groundwater Recharge

Natural recharge generally occurs in permeable soils, sediments and fractured bedrock during periods when precipitation exceeds evapotranspiration or when streams are flowing. When rain falls faster than it can soak into the ground, runoff occurs and limits the amount of water that is recharged. Other factors that can limit recharge include the presence of hard surfaces, such as roads and driveways, the presence of shallow clay layers, and areas with a shallow water table. In many areas of California, stream channels typically provide a significant source of recharge to groundwater basins. The identification and protection of groundwater recharge areas is an important step in sustaining groundwater basins.

Seepage from canals, surface reservoirs, septic and leaking water supply systems, urban watering and storm runoff also contribute to recharge. Recharge can also result from irrigating crops. When applying irrigation water faster than a crop can absorb or water can evaporate, the excess sinks through the root zone and gradually recharges groundwater.

Recharge can be enhanced by placing water in spreading basins to percolate into the ground, modifying stream channels and surface topography to slow the rate of runoff and increase infiltration of stormwater, and inserting water into recharge wells.

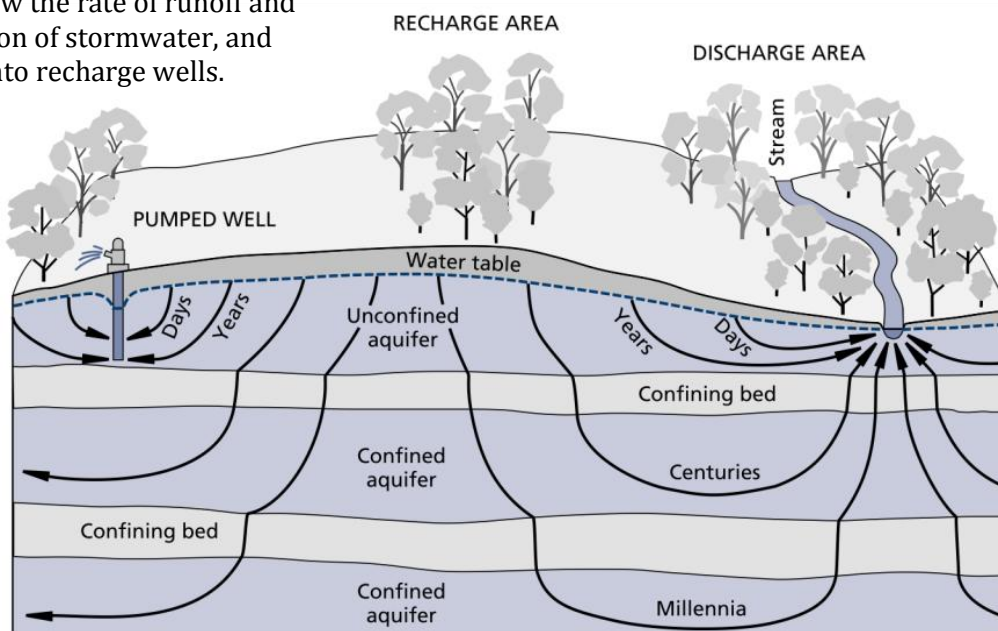
Groundwater Discharge

The speed and manner of groundwater movement from recharge areas to discharge areas where it exits the aquifer, depend on the permeability of the various materials (sediments, soils, rocks) that the water must flow through, the hydraulic gradient of the water moving underground, hydraulic conductivity of the geologic formation, and the cross-sectional area of the aquifer (if the aquifer is a hallway, a door frame in the hallway is the cross-sectional area).

Most natural discharge occurs at springs, seepage into stream channels, wetlands and seasonal lakes in desert areas. In some basins, subsurface flow into another basin or into the ocean discharges significant amounts of groundwater. Humans can also significantly contribute to discharge by pumping groundwater from water wells.

Wetlands or lakes can form when the water table lies close to or at the ground surface. The wetland may disappear if groundwater levels are lowered. Water evaporates from damp soil marginal to the wetland and is removed by the roots of plants.

Figure 6: The figure illustrates groundwater system recharge and discharge areas and estimates time for a water molecule to flow along various paths from recharge to discharge areas.



Basin Yield

Basin yield is the average amount of water that can be extracted annually from an aquifer or groundwater basin, without causing undesirable results, such as permanently lowered groundwater levels, land surface subsidence, degraded water quality in the aquifer, or decreased stream flow. Well pumping may vary above or below the long-term yield during drought or wet years, or as part of basin management plans. If water conditions (precipitation, recharge, natural discharge, pumping, etc.) in a basin change, the basin yield may change.

Basin yield does not equal groundwater storage. Groundwater storage in a basin is the amount of usable water that can be technically and economically extracted from a basin and is likely to be a very large number compared to the yield. For example, many arid groundwater basins may contain a large amount of usable groundwater that accumulated from low amounts of annual recharge over a significant time period (thousands of years or more). The low annual recharge provides a low basin yield. If annual extractions consistently exceed this yield, the withdrawals will remove more groundwater than can be replaced by natural recharge (“mining the groundwater”).

The term “safe yield” is often used in judicial proceedings. It is determined by technical professionals and subsequently interpreted by courts to define the legal rights to extract groundwater in a basin.

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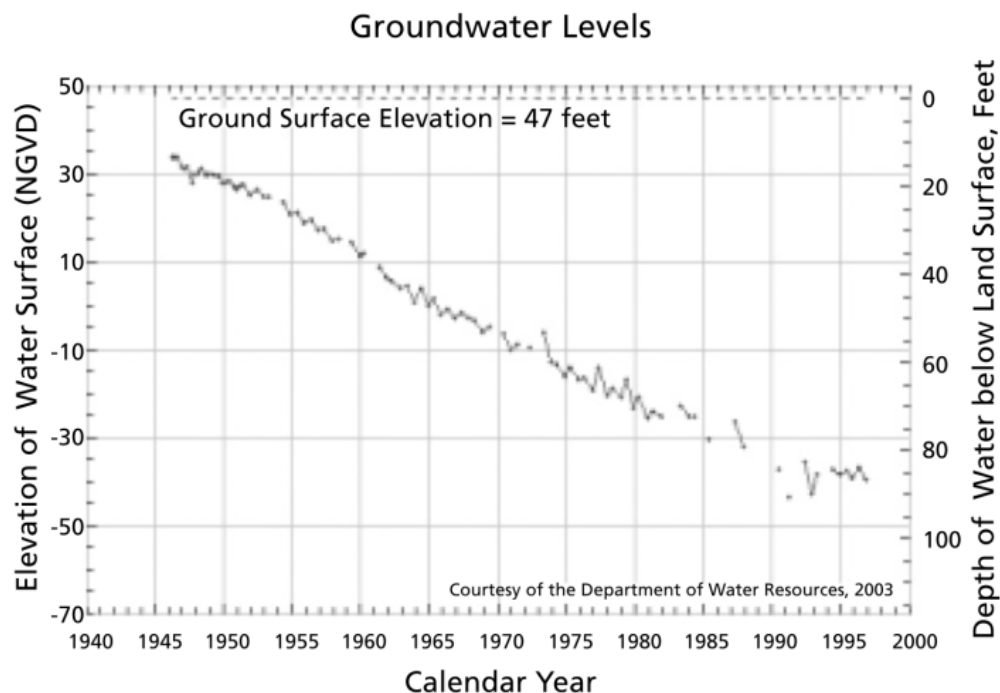


Figure7: A water well hydrograph showing the long-term change in the groundwater level in the well over time. This well shows an overall downward change of more than 70 feet in 50 years, with seasonal changes of a few feet.

information for tracking how the aquifer behaves over time during pumping and recharge.

Just a few measurements are not adequate for understanding how the aquifer responds to water use and recharge and to make long-term projections of groundwater levels in response to pumping. Instead, groundwater level measurements should be collected consistently over a long period (decades) so that changes in groundwater levels can be assessed and management strategies can be developed.

Overdrafting groundwater basins may have significant negative consequences, such as water quality degradation, saline intrusion, surface subsidence, and increased costs to pump groundwater and replace wells.

Limited droughts, or isolated periods of abnormally low rainfall, do not cause overdraft. Droughts temporarily reduce the amount of water available to recharge the

basin, and if pumping rates remain the same, groundwater levels often exhibit declines during drought periods. This reduction in groundwater storage is similar to the lower water level in a surface-water reservoir during a drought. When the drought is over, groundwater levels often exhibit increasing or rising trends (again assuming pumping rates remain the same), just like a surface water reservoir.

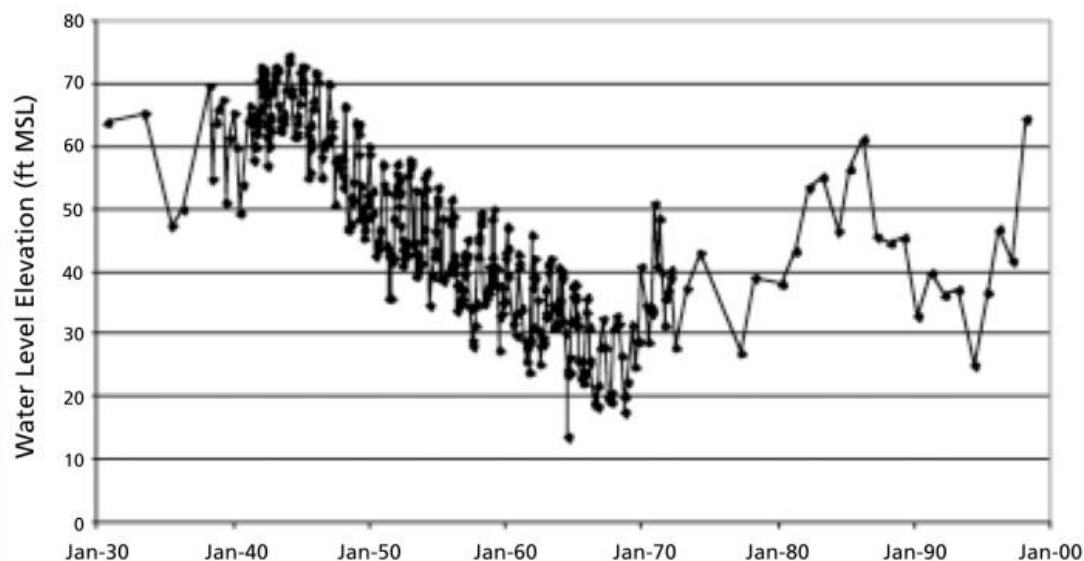


Figure 8: A water well hydrograph clearly showing the seasonal changes of 10 to 20 feet in the groundwater level in the well each year.

Water Wells

Water wells can be thought of as windows to the aquifer and provide the only opportunity to collect direct information on the groundwater system. Water wells are typically quite expensive to install. Therefore, collecting quality information during water well drilling, constructing and testing is important.

Wells and How They Work

A well is a hole drilled below the ground surface into the saturated zone. Wells typically have screens at intervals to allow groundwater to flow into the well from the most productive aquifer(s). All water wells are required to prevent foreign substances from entering the well and the aquifer. This is called surface completion and consists of installing casing and sanitary seals. The casing also keeps the material of the aquifer from falling into the well and provides space for a pump and a filter pack. Well casing typically consists of steel pipe, but can also consist of plastic pipe (e.g., PVC) for some applications. The most common pumps used in wells today are line-shaft turbines and submersible turbine pumps. A well also could be an "open hole" completion below the sanitary seal and casing as in many bedrock wells. A well that is built correctly and is properly developed will not impede the flow of groundwater from the aquifer into the well or allow sediment from the aquifer to enter the well.

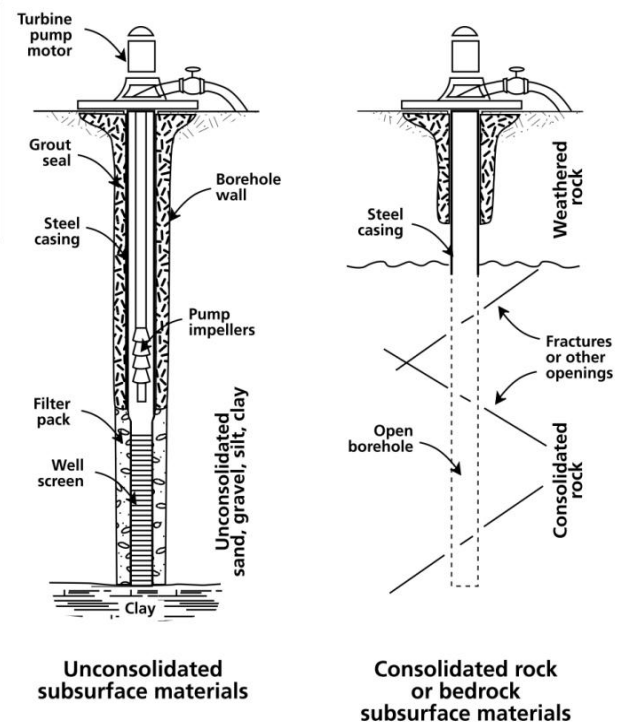


Figure 9: Water well construction diagram for sand or gravel, known as unconsolidated material and bedrock completion.

Until the well pump is turned on, the groundwater level in the well will be that of the local water table for an unconfined aquifer or the potentiometric surface in a confined aquifer. When the pump is turned on, the groundwater inside the casing is pumped to the surface, and the water level within the casing is lowered. The difference in pressure between the water level in the casing and the water level in the aquifer creates a hydraulic gradient between the aquifer and the casing. As a result, groundwater flows from the aquifer into the casing to replace the water that is being removed.

Water flow in uncased wells is similar. The rate at which groundwater flows from the geologic formation into the casing is determined by the permeability and storage capacity of the aquifer material and efficiency of the well at pumping water.

GROUNDWATER IN THE SANTA ROSA PLAIN

The Santa Rosa Plain groundwater basin covers an area of approximately 80,000 acres and is home to approximately half of the population of Sonoma County, including the Cities of Santa Rosa, Rohnert Park, Cotati, Sebastopol, Town of Windsor, , and unincorporated areas of Sonoma County. The groundwater basin is bounded on the northwest by the middle reach of the Russian River floodplain and by the upland hills of western Sonoma County on the remaining western boundary. The southern end of the Santa Rosa Plain is marked by a series of low hills just south of Cotati, which form a drainage divide that separates the Santa Rosa Plain from the Petaluma Valley. The Santa Rosa Plain is bounded to the east by the Sonoma Mountains south of Santa Rosa and the Mayacamas Mountains north of Santa Rosa.

Santa Rosa Creek, Mark West Creek, and the Laguna de Santa Rosa (Laguna) provide the main surface drainage for the area. Santa Rosa and Mark West Creeks originate in the mountains to the east of the basin. The Laguna runs along the western margin of the basin and is a swampy, intermittent drainage course that drains much of the groundwater basin.

The groundwater system beneath the Santa Rosa Plain provides numerous benefits to the region, including rural residential and municipal water supplies, irrigation water for agriculture, and baseflow to streams and

surface water bodies.

Water supply in the Santa Rosa Plain is met by combinations of surface-water delivery from the Russian River and ground water from water wells. There are over 12,000 permitted water wells in the basin and these provide water for a variety of uses, including both urban and rural areas, agricultural irrigation, and commercial and industrial uses. Future growth in population and demand for water coupled with constraints on existing surface water sources are likely to increase stresses on the region's groundwater resources.

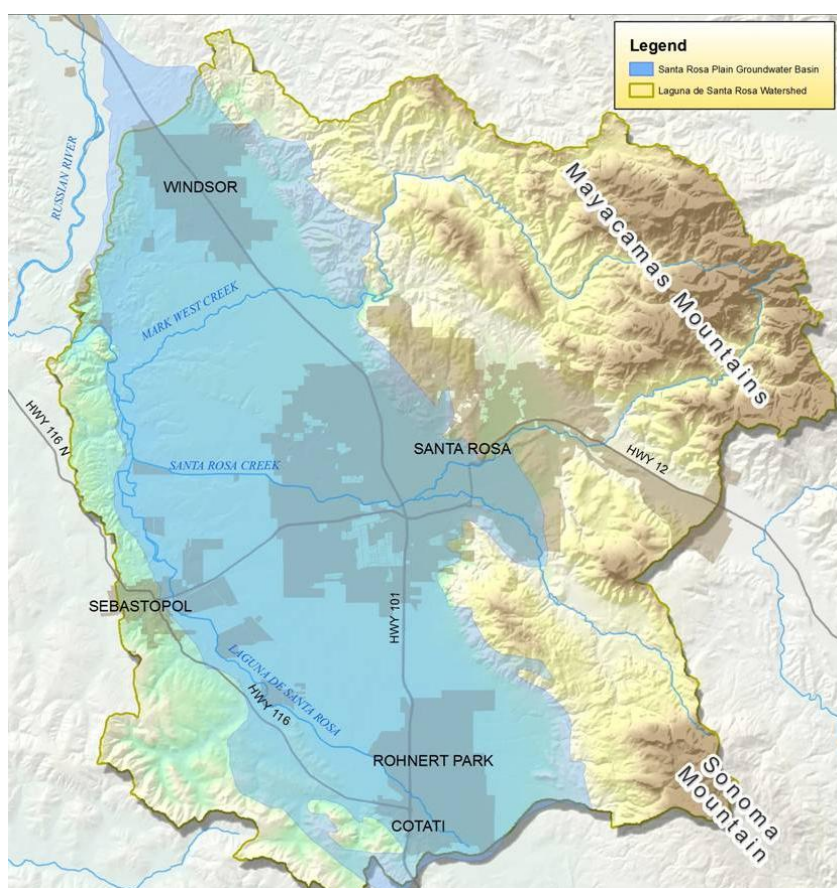


Figure 10: Map of Santa Rosa Plain Groundwater basin (blue) and Laguna de Santa Rosa Watershed (yellow).

Santa Rosa Plain Geology

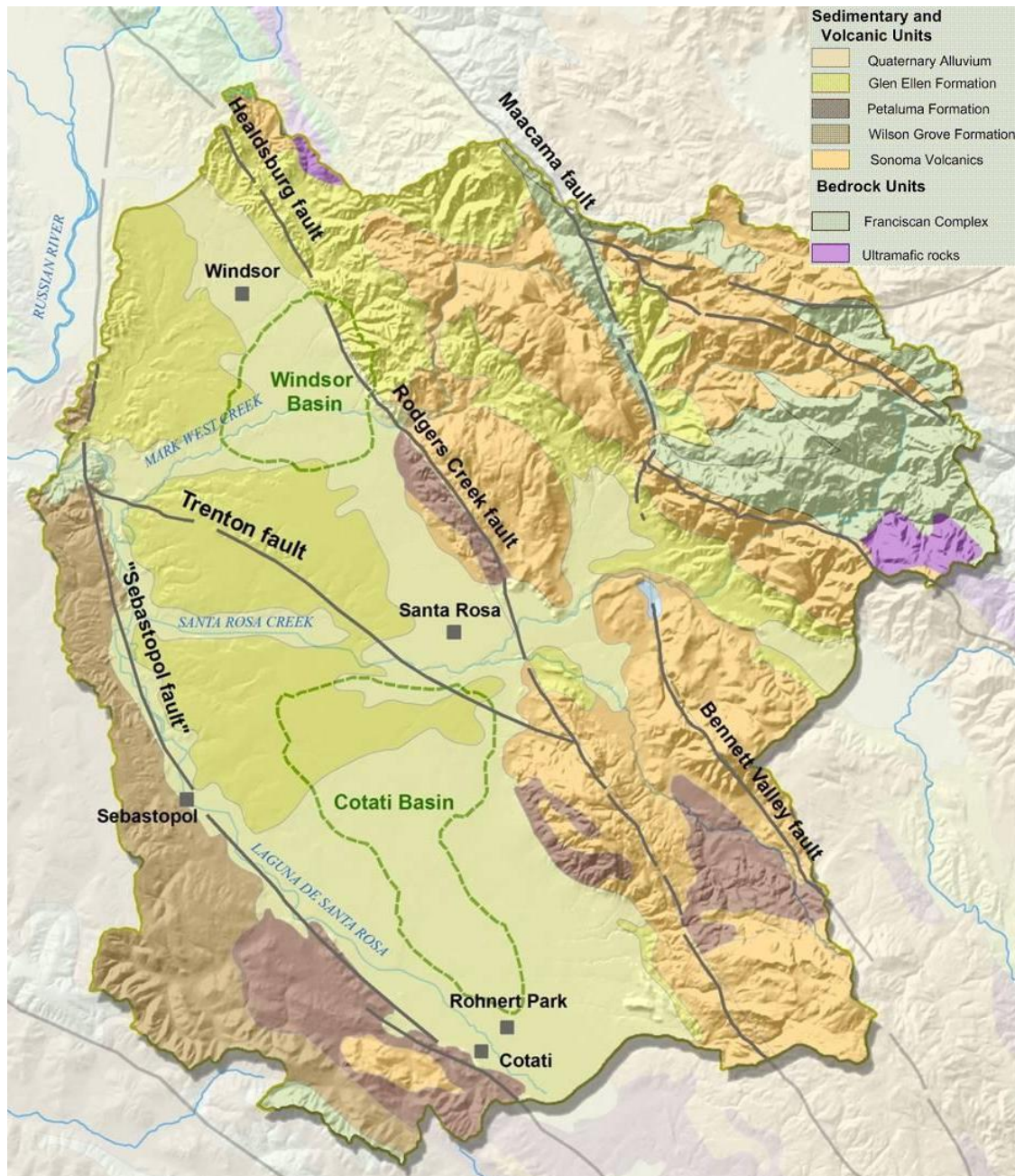


Figure 11: Generalized Geologic Map for the Santa Rosa Plain Area showing the distribution of geologic units.

The geology of the Santa Rosa Plain groundwater basin is very complex due to the wide variety of geologic units in the basin and the numerous fault zones in the region. A large portion of Sonoma County is made up of bedrock which does not hold much groundwater. In the Santa Rosa Plain, however, thick sedimentary layers and volcanic rocks overlie this bedrock and are capable of storing and yielding large quantities of groundwater. The four main geologic units which form the primary aquifers in the Santa Rosa Plain are sedimentary deposits of the Alluvium and Glen Ellen Formation, the Wilson Grove Formation,

the Petaluma Formation, and the Sonoma Volcanics. These geologic units are shown on the Geologic Map for the basin in Figure 11. The basin's best water-producing units are stream channels filled with alluvial sands and gravels; basin-fill alluvium and alluvial fan deposits that connect the Santa Rosa Plain with its bordering hills; and massive sandstone units of the Wilson Grove Formation extending beneath the basin from the low western hills. The Sonoma Volcanics, a thick sequence of lava flows present along the eastern boundary of the basin, and the Petaluma Formation, a shale and sandstone unit that extends beneath much of the deeper portions of the basin, produce variable amounts of water.

The basin is divided by northwest trending faults, which may serve as groundwater barriers, and also offset the rock units. Recent studies conducted by the USGS have revealed the basin is subdivided into two primary compartments termed the Windsor sub-basin in the north and the Cotati sub-basin in the south, which are separated by the Trenton fault. These two areas represent the deepest parts of the basin and range from 6,000 to 10,000 feet deep.

Groundwater Recharge and Discharge in the Santa Rosa Plain

Groundwater within the Santa Rosa Plain is generally present under unconfined conditions, except locally in the vicinity of clay or silt horizons where conditions may be semi-confined or confined. In the Santa Rosa Plain, significant natural recharge locations are stream channels located along the eastern portions of the basin and outcrops of permeable sedimentary units along the southwestern margin of the basin. Clay-rich sediments cover portions of the central southern Santa Rosa Plain, and extend northward along the Laguna de Santa Rosa, impeding water infiltration.

Groundwater is removed from the basin through wells and leaves the basin as both subsurface outflow and groundwater discharge to the Laguna de Santa Rosa. As shown in figure 12, groundwater generally flows from the recharge areas (e.g., highlands to the east and west of the basin) toward discharge areas (primarily the Laguna de Santa Rosa). This general pattern can be disrupted locally due to exchanges with other surface water features within the basin, the presence of fault zones and the pumping of groundwater from water wells.

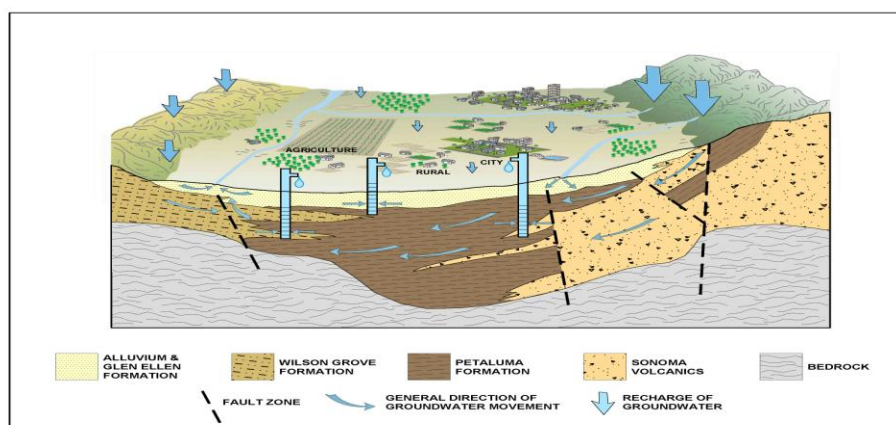


Figure 12: Conceptual Block Diagram of the Santa Rosa Plain showing how groundwater generally moves through the basin.

Groundwater Level Trends

Routine measuring and monitoring of groundwater levels within wells has historically been relatively sparse within the Santa Rosa Plain. In general, groundwater levels in shallow aquifers fluctuate seasonally with rainfall and are largely stable over time. In contrast, groundwater level trends for deeper water wells show a combination of trends over time. Some wells show overall stability,

some show overall declining trends and some show historical declining trends followed by recent increases in groundwater levels. The greater occurrence of declining groundwater level trends within the deeper zone wells is likely related to both the larger sized wells completed in deeper zones and the greater amount of time these deeper zones require to recharge.

Hydrographs of Select Shallow Wells

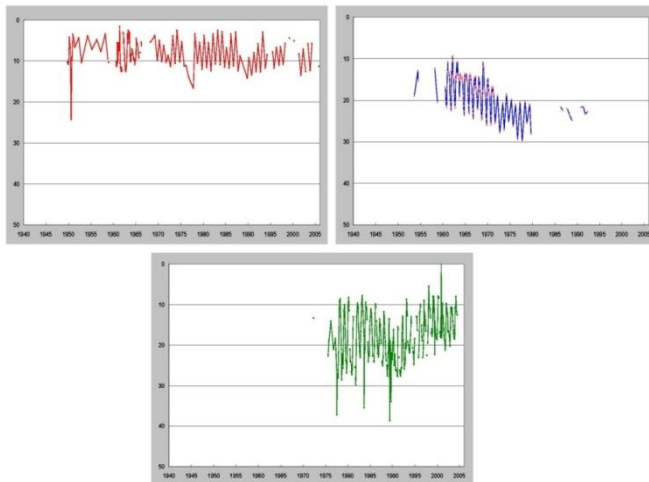


Figure 13: Groundwater-Level Hydrographs of Select Shallow Wells (less than 100 feet deep) within the Santa Rosa Plain. The Red and Blue graphs are from shallow wells located in the northern portions of the basin and the Green graph is from a well located in the southern portion of the basin. Shallow wells generally show fluctuations seasonally with rainfall and are largely stable over time.

Hydrographs of Select Deeper Wells

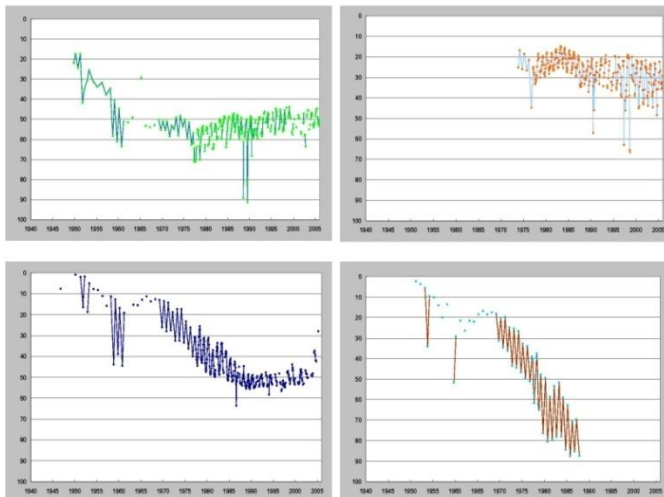


Figure 14: Groundwater-Level Hydrographs of Select Deeper Wells (greater than 200 feet deep) within the Santa Rosa Plain. The Green graph is from a well located in the northern portion of the basin, the Orange graph is from a well located in the central portion of the basin and the Blue and Burgundy graphs are from wells located in the southern portions of the basin. A greater occurrence of declining groundwater levels is observed within deeper zone wells.

USGS Study

The most recent basinwide studies of the Santa Rosa Plain Groundwater Basin were completed over 25 years ago. As part of an ongoing program intended to enhance the current knowledge regarding groundwater resources within Sonoma County, the United States Geological Survey (USGS) initiated a five-year cooperative study of groundwater resources within the Santa Rosa Plain Groundwater Basin in 2005. The cooperative study is being conducted by the USGS in partnership with the Sonoma County Water Agency, County of Sonoma, City of Santa Rosa, City of Rohnert Park,

City of Sebastopol, City of Cotati, Town of Windsor, and Cal-American Water Company. The study will be completed by the end of 2011, with publication of the study results scheduled for early 2012. Results from the study will provide stakeholders with tools to assist in evaluating the hydrologic impacts of future climate-change scenarios and alternative groundwater management strategies for the basin. Additionally, the study could potentially form the technical foundation for a local non-regulatory groundwater management planning process.

Managing Groundwater

Legal Concepts and Groundwater Rights

In California, there is not a statewide process for regulating or permitting groundwater. The water belongs to the state but property owners have a right to use the water beneath their land, with the stipulation that they put the water to reasonable and beneficial uses and do not waste it. All wells must be installed by a state licensed driller in the state of California.

With important exceptions, a property owner has the “appropriative” (“overlying”) right to install a well and start pumping the groundwater. Exceptions include legal actions that detach the right to pump groundwater from the overlying property, and adjudication of a whole groundwater basin. In an adjudication, the court decides who can pump and how much. In addition, some cities have zoned areas to disallow wells, in return agreeing to supply city water to those zones.

Under a California legal doctrine, the state may require permits for withdrawing groundwater in areas determined to be in direct connection with an adjacent surface stream river. In those cases, the state must perform a study involving groundwater experts and engineers to determine at what distance the groundwater remains “under the influence” of the surface water.

Groundwater is a “common pool” resource because many users extract water from single aquifers and multi-aquifer basins. If the combined rate of extraction exceeds the recharge, groundwater levels will decline, which tends to increase costs of pumping and or even replacing wells. Groundwater declines can raise arguments over “third party impacts.” These arguments can continue for many years and even decades.

If contending water users in a groundwater basin cannot resolve their issues, and one or more individuals pursue resolution through a lawsuit, the result may be adjudication. When a basin is under adjudication, courts establish the safe yield of the basin and decide how much each individual water user can extract annually. The process can take a long time, because of the number of parties involved, general lack of judicial experience in water law and science, and California's lack of special water courts. These costly legal battles involve lots of experts, attorneys, and multiple studies.

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Possible Groundwater Planning Options

Groundwater planning and management programs integrate actions aimed to achieve the long-term sustainability of the resource, which is often of unknown quantity, quality, recharge and use.

No Groundwater Planning

Ignoring potential water supply issues often results in lawsuits, leading to lengthy and costly adjudication. Everyone loses their water rights and the courts decide who is entitled to pump and how much.

Status Quo

With the status quo, local agencies separately plan projects without coordination or cooperation. Comprehensive, integrated planning is lacking. Stakeholder involvement is usually absent. The "hands off" status quo can thrust areas into court if local stakeholders become worried about their water supply.

Develop a Plan

Developing a comprehensive groundwater management plan is best addressed with broad stakeholder participation. In many cases, a stakeholder assessment is the first step for testing the waters, exploring the public's knowledge about groundwater issues and determining if they are ready and willing to participate.

A groundwater plan can be short or long, complex or relatively simple, and consists of the following basic elements:

- **Goals and management objectives** – examples such as sustaining the resource for future generations, maintaining or stabilizing groundwater levels, protecting water quality, enhancing or maintaining native ecosystems, etc.
- **Proposed actions** to meet the objectives typically include a monitoring program and evaluations, some or all the voluntary components set out under AB3030, and the mandatory components under SB1938. Including these elements provides eligibility for state funds
- **Time schedule and budget** to implement those actions, such as water-level monitoring, data management and evaluation, and regular reporting and review
- **Monitoring of a groundwater basin** involves measuring water levels and collecting periodic water samples from a cross section of wells in the basin, to understand seasonal and long-term trends in groundwater levels and evaluate water quality. Collecting this kind of data does not require monitoring every well in the basin. Ideally, a small portion of stakeholder well owners volunteer to allow monitoring of wells on their properties.

Institutional Authority/Management Structure under a Groundwater Plan

The variety of institutional/management options include:

- **Coordinated Agreements** – can provide written tool for studies and development of a groundwater basin model, joint capital projects, and joint operational policies. Need unanimous agreement between parties, and can take significant time.
- **California Groundwater Management Planning Act (AB3030)** – local agency groundwater management; permissive legislation for agreements between public and private parties; conveys powers of a replenishment district. Based on voluntary cooperation among stakeholder interests.
- **General Act Districts** – indirectly managed through assessments and incentives; no authority to regulate or limit extractions. Potential for only limited jurisdiction over the groundwater basin.
- **Water Replenishment Districts** – can obtain supplemental water supplies to directly or indirectly replenish overdrafted groundwater basins. Some have water quality authority.
- **Special Act Districts** – powers and organization customized for an area's specific issues, political, and technical characteristics; generally empowered to conduct studies, regulate extractions, and replenish extracted supplies.
- **City and County Powers** – comprehensive or general plans; police power regulation; management through groundwater ordinance; seamless coordination with AB3030 Plans.
- **Adjudication and Physical Solution** – exerts outside control over water extraction; can create comprehensive physical solution for basin management; court decides as a result of a lawsuit. Generally time consuming and very expensive; indefinitely continuing jurisdiction and water master administration of final judgments.

Groundwater Management Planning in California

Approximately 150-200 groundwater management plans have been developed successfully in the state. Each basin has unique needs, setting, objectives, and actions planned. Many of these programs provide only for reporting of measured water levels and limited water quality, and do not record the water volumes extracted (pumpage). Other basins, and principally adjudicated basins, do require pumpage reporting. Still other basins, such as the Sonoma Valley groundwater management plan, have opted for voluntary monitoring programs. It is up to the stakeholders who develop the plan to decide how to best manage their basin.

Groundwater Management Planning: Pros & Cons

With Management = Benefits	Without Management = Danger
Ensure long-term viability of the groundwater aquifer	Possible permanent damage to aquifer
Maintain water quality	Poor groundwater quality due to accelerated geothermal upwelling and concentration of total dissolved solids in older water
Prevent aquifer depletion and stabilize groundwater levels	Declining basin groundwater levels over time
Ensure safe drinking water	Increased water treatment costs
Meet existing and future water demands	Drilling deeper wells at greater expense
Diversify supply with conjunctive use	Potential land subsidence
Stakeholders decide and agree on groundwater management and maintain local control	Potential legal battles or adjudication for management control
Coordinate with and support creek restoration efforts	Decreased flows for creeks
Sustain groundwater quantity and quality for future generations through groundwater management	Uncertain quality and quantity of groundwater in the future without groundwater management
Increased opportunity for state funding for water projects	Increased pumping costs